L11: Entry 13 of 13 File: USPT Dec 19, 1995

DOCUMENT-IDENTIFIER: US 5477459 A
TITLE: Real time three-dimensional machine locating system

Abstract Text (1):
A method and system for locating the point P.sub.0 which defines the location of a machine, e.g. an earth moving machine, a surveying or locating machine, etc., in relation to a tract or area of interest by measuring the angles defined by two different sets of reference points selected from at least three reference points that are in known relation to the tract or area.

Brief Summary Text (2):
In the field of surveying and distance measuring equipment, there is a need to determine the position of objects (markers, etc.) relative to fixed points. There are several methods for doing this. In general, two approaches are used. One method involves the measurement of linear distances; another, the measurement of angles and distances. Usually a construction site is surveyed and the topography is plotted before work begins. Fixed flags tell the equipment operators to either cut or fill a particular location. An iterative process of survey and grade is used to work the site into the final topography prior to actual construction. This iterative process is slow and laborious and therefore expensive. Since there is a great deal of human work involved, it is also error prone.

Brief Summary Text (17):
U.S. Pat. No. 4,774,403, to Arts, on Sep. 27, 1988, discloses a position measuring device using a triangulation scheme for position sensing. A laser diode projects a spot upon a target surface. The image of the spot is focused on a charge coupled device linear image sensor. The image of the sensor is indicative of the distance from the device to the target surface.

Brief Summary Text (18):
U.S. Pat. No. 5,032,023, to Schneiter, on Jul. 16, 1991, discloses an apparatus for a variable depth triangulation ranging system, the ranging system including means for emitting a fight beam, means for focusing an emitted light beam on an object, and lens means for imaging reflected light onto an input end of said apparatus. The apparatus includes an optical fiber bundle, the bundle including an input end and an output end, the bundle input end being disposed so as to intercept transmissions from said lens means, means for scanning, in a time-based manner, the bundle output end, the scanning means being configured to generate a time-based signal indicative of a light signals present at the bundle output end, and means for calculating system geometry and range from the time-based signal.

Brief Summary Text (19):
Tanabe, Toru, Experimental Validation of GPS-INS-STAR Hybrid Navigation System for Space Autonomy, International Astronautical Congress, 39th, Bangalore, India, Oct. 8-15, 1988. 12 p. (Abst.) describes the gps-ins-star hybrid navigation system concept combines these three sensors: a ins-star hybrid system, a gps-ins system, and a gps-ins-star system. It was concluded that a star field simulator had been developed to serve as a source of radiation for the astro star tracker. A minimum

of three simulated guide stars with variable magnitudes were needed to fully test the star tracker performance under simulated mission conditions.

Brief Summary Text (23):
Van der Grinten, H. F., Navigation, vol. 22, Summer 1975, p. 128-134, (Abst), cataloged forty-six celestial lines of position obtained aboard a ship at sea are compared with the position as interpolated between NAVSAT fixes. Least squares adjustment of the combined celestial lines of position yielded a fix with an essentially circular error ellipse. The directional distribution of stars was well balanced. The navsat positions and the combined celestial fix were found to be substantially in agreement. Using the NAVSAT positions as a reference the mean error of well balanced celestial fixes as derived from the data and the method of least squares can be expected to be less than 0.8 nm for a 3-star fix and 0.1 nm for a 46-star fix. These results permit the construction of probability contours around well balanced celestial fixes consisting of various numbers of observations.

Brief Summary Text (24):
Wertz, J. R., Spaceflight, 14; June 1972, p. 206-216, (Abst) asserted that the most essential requirement is an atlas of the three-dimensional positions of all of the stars in the region to be explored and any bright navigational stars that might lie outside this region. In addition to accurate stellar positions, data about the velocities of the listed stars are required together with some means of accurately identifying individual stars--specifically, their absolute magnitudes and detailed spectra. Given the interstellar navigation atlas, there are many ways for the navigator to determine his position and velocity. Effects of high speed motion are discussed, together with the possibility of visual disorientation due to a displacement of the star field caused by small shiets of location.

Brief Summary Text (25):
A method for determining the position of an object in a 3D space has been proposed. An M-array LED pattern is projected onto the object through a lens and the projected array is observed with a CCD camera. Each element of the M-array is time modulated with an M-sequence having different phase. The cross-correlation function between the observed signal and the reference gives information about the phase, and thus the point-to-point correspondence. Then simple mathematical relations are used to determine the exact 3D position of the object. The proposed method is robust to noise and highly efficient. (Measurement of 3-dimensional position by use of M-array projection, Jing-Min Sham Kashiwagi, H.; Sakata, M., dournak Transactions of the Society of Instrument and Control Engineers, vol.25, no.4 p.389-95, 1989).

Brief Summary Text (26):
The monitoring of the motion of an arbitrary mandibular point has been accomplished using a recording system that includes three cameras. Each camera contains a cylindrical lens and a linear optosensor (CCD). Two extra-oral lightweight target flames (2 g) containing each three light emitting diodes are fixed on the patient's teeth. The system fires each LED cyclically and computes their three-dimensional coordinates in a reconstruction unit. From these coordinates another processing unit computes the three-dimensional coordinates of an arbitrary jaw point in a head fixed coordinate system. The computed trajectories are drawn on-line with the help of dedicated 3D viewing hardware on a CRT where they can be directly rotated and zoomed to follow intricate motion details. (Real-time, noninvasive recording and three-dimensional display of the functional movements of an arbitrary mandible point, Mesqui, F.; Kaeser, F.; Fischer, P., Proceedings of the SPIE--The International Society for Optical Engineering vol.602 p.77-84, 1986).

Brief Summary Text (27):
An optical correlator uses a light emitting diode array, in which analog signals from two spaced sensors are correlated in order to locate and track a target. One

signal is clipped and digitized and clocked through a shift register, and the other signal is delayed. The shift register is coupled to an LED array, element for element. Each shift register element modulates its corresponding LED element. The delayed signal is also connected at its output to the LED array via a transistor, and modulates each LED element. Therefore, the LED elements emit light in proportion to the product of the two signals. The emitted light is focused onto a CCD imaging array where it is integrated over a period of time before being sent to an integrator and output display device. The output is the correlation function versus the time delay between the two signals. Successive outputs display the movement of targets. Circuit design mitigates inherent errors within the system. (Acoustic Signal Optical Correlator Using a Light Emitting Diode Array, Fogarty, E. J. U.S. Pat. No. 4,805,158, Feb. 14, 1989).

Brief Summary Text (29):
A helmet mounted sight system using CCD technology is described which can be used outside the restricted viewing area of the head up display, but with reduced accuracy. It is noted that the system consists of two pans: the helmet mounted display and the helmet optical position sensor. It is reported that a limited amount of essential information (i.e. aiming reticule, weapon lock, etc.) can be displayed on the surface of the helmet mounted display, noting that the limit is set by the pilot's inability to assimilate further data. Attention is given to the helmet optical position sensor which consists of two triads of LED's mounted on the sides of the helmet and two CCD cameras mounted in the cockpit. Finally, it is concluded that using the CCD to its full capability enables a small compact system to be produced without the need for fast analog to digital converters and a large digital store. (A helmet-mounted sight using C.C.D. technology, STEPHENSON, M.D., Radio and Electronic Engineer, vol. 49, Oct. 1979, p. 511-513, 1979).

Brief Summary Text (32):
U.S. Pat. No. 4,994,907, to Allen, on Feb. 19, 1991, describes a color sensing CCD with staggered photosites, e.g., a line sensor with photosites accurately located for color scanning. The sensor includes a plurality of photosites arranged in a two-dimensional, staggered pattern which is repeated across the length of the sensor. Only one photosite is located for every direction perpendicular to the axis of the line image. Individual color filters extend over all the photosites located at the same perpendicular distance from the line image axis. In one embodiment, the filters are disposed on separate transparent members which are aligned and assembled over the photosites.

Brief Summary Text (33):
Mollow, P. A., et al, Journal: Proceedings of the SPIE--The International Society for Optical Engineering, Vol.1347 p. 123-30, 1990 (Abstr.) describes a system using one-dimensional optical devices to perform the desired two-dimensional correlation. The two-dimensional correlation is performed as a series of multichannel time-integrating correlations between each input image line and a reference template that is stored in an electronic memory. The rows of the reference template are introduced into the processor in parallel using a one-dimensional laser diode array. The correlation in the vertical direction is performed using a modified charge-coupled device operating in the shift-and-add mode. Key features of the system include the random access template memory, the custom laser diode array consisting of 64 individually addressed laser diodes.

Brief Summary Text (34):
The basic mathematical formulation of a general solution to the extraction of three-dimensional information from images and camera calibration has been described. Standard photogrammetric algorithms for the least squares estimation of relevant parameters are outlined together with terms and principal aspects of calibration and quality assessment. Three-dimensional testfields and independently determined reference coordinates were used for quality assessment using off the shelf equipment to an accuracy of 1/20/ sup th/and 1/50/ sup th/ of the pixel

spacing in row and column direction respectively has been achieved. The system was used to calibrate the vision system of a ping-pong playing high-speed robot tracking table-tennis balls with a 50 Hz rate. Calibration of CCD-cameras for machine vision and robotics, Beyer, H. A., Journal: Proceedings of the SPIE--The International Society for Optical Engineering vol. 1197 p.88-98, 1990 (Abstr). Two sensors were used in a system for autonomous rendezvous and docking manoeuvres in space. The first is a proximity sensor, which is dedicated for distance and angle measurements. The sensor's equipment consists of three units: the position-sensitive detector, the illuminator and the common optics including a c.w. laser rangefinder. On the target side a corresponding reflector complements the necessary equipment to measure distance and angle deviation from boresight direction. The operation wavelengths are between 790 and 850 nm. The second is a high-resolution CCD-camera in combination with a dedicated S/W processor, which is used for distances between 2 m and 100 m. On the target side, a three-dimensional symmetric pyramid reflector configuration is used. The camera processor transforms the actually depicted reflector configuration differences to the expected reflector configuration for boresight position into distance and position information for six DOF. This method can achieve faster update repetition rates (10 Hz) than a common pattern recognition technique. The camera is equipped with a 880 nm wavelength LED illuminator. Optical sensors for position measurements, Schroer, G. et al, Sensors and Actuators vol. 17, no.3-4p.329-38, 1989 (Abstr).

Brief Summary Text (35):
Optical correlators have been used to investigate real time pattern recognition. 1-D devices have been used to perform the two dimensional correlation in real time by using an array of light emitting diodes (LED's) to input an electronically stored reference image into the processor in parallel. The input scene data is introduced into the processor one line at a time using an acousto-optic device (AOD). Multichannel time integrating correlations are performed in the row direction using the AOD and in the column direction using a charge coupled device (CCD) operating in the time delay and integrate mode. A processor that correlates a 64.times.44 pixel binary reference image with a 256.times.232 input scene at video rates was used. A second correlator is a space integrating Fourier transform based correlator. A magneto optic-device (MOD) is used at the Fourier transform plane to rapidly change filter functions. Stalker, K., et al, International Congress on Optical Science and Engineering, 24-28 Apr. 1989 (Abstr).

Brief Summary Text (36):
In another application, a new sensor that can measure the two-dimensional environment of a robot has been reported. This sensor consists of a laser diode and a charge coupled device (CCD) linear array sensor built in a simple optical imaging system with a rotating mirror. The measuring range of this sensor is 250 mm to 6000 mm, and the measuring time for one direction is 1 ms to 10 ms. It can measure distances more than 200 points to obstacles or walls around robot per second. The position of the walls is recognized from these measuring points using a microcomputer system. Development of environment sensor for vehicle robot, Takamasu, Kiyoshi, Journal of the Robotics Society of Japan, Volume: 5, Issue: 3, Pages: 199-202, June 1987 (Abstr).

Brief Summary Text (37):
U.S. Pat. No. 4,970,653, to Kenue, on Nov. 11, 1990, discloses an image processing method that operates on an image from a CCD camera viewing a roadway scene in front of a vehicle to detect lane markers and determine the relationship of the vehicle to the lane. Obstacles in the lane near the vehicle are detected and a warning is given to the driver. The method uses template matching techniques or a hough algorithm to detect the lane markers or road edges.

Brief Summary Text (38):
The components and instruments necessary to carry out the present invention are available commercially. (Components and peripherals, buyers guide, EDN VOL.: v33

n15 p253(27), Jul. 21, 1988, Lasers & Optronics, v7, n4, p76(3), April, 1988.) For example, Infrared Associates' infrared detectors and related accessories have applications in analytical instruments, medical thermography, thermal imagers, air-borne scanners, high-altitude balloon experiments, laser range finders and high-speed missiles. They come in single and multi-element arrays and can be packaged in a variety of metal or glass dewars, which can be cooled or uncooled. The matched preamplifier circuits can be provided in single or multi-channel configurations. Infrared Associates, Inc., 1000 Route 130, Cranbury, N.J. 08512. Automated Waveform Digitizers LeCroy Corp.'s line of high-performance automated single-channel, waveform digitizers provides high speed wave measurement and analysis instrumentation. Among the benefits the devices provide are higher accuracy measurements, extended memory-length waveform recording, pre-and post-trigger waveform recordings, high resolution transient capture, digital signal processing and analysis and total programmability. LeCroy Corp., 700 Chestnut Ridge Rd., Chestnut Ridge, N.Y. 10977-6499. A Red-emitting diode laser is available in the visible-wavelength range. NEC's Model NDL 3200, operates at room temperature and will run more than 3,000 hours without performance degradation. Fabricated in indium gallium arsenide phosphide, the device emits a minimum of 3 milliwatts at 680 nanometers. The diode has a back-facet monitor photo-diode and is offered in a three-pin, 9-millimeter TO can. This diode laser has rise and fall times of 400 nanoseconds. NEC Electronics, Inc., P.O. Box 7241, Mountain View, Calif. 94039. The 4000 series of lasers from Continental Laser Corp. feature a two-tube tandem design which virtually eliminates any down time, according to the manufacturer. Two large-diameter solid Invar rods provide a 50-inch resonator structure for stability. The systems are designed for OEM, industrial, medical, entertainment and scientific applications. Multi-line power specifications are 8 to 12 W for the argon models and 2.5 to 4 W for krypton. Light regulation, prism wavelength selector, remote-control module and etalon assembly options are available. Continental Laser Corp., 805 E. Middlefield Rd., Mountain View, Calif. 94043. XMR Inc.'s Model 5100 excimer laser is designed specifically for a long lifetime of industrial use. Capable of generating a continuous 150 watts of average power or 200 watts for shorter periods, the 5100 features a magnetically switched PFN and can be incorporated into custom laser-based systems. XMR, Inc., 5403 Betsy Ross Dr., Santa Clara, Calif. 95054. Air- and water-cooled argon and krypton lasers, American Laser Corp., range in output power from 1 to 8 watts, continuous wave, multi-time configuration. The units are available in argon, krypton and mixed gas and offer additional features such as single-line operation, TEM sub.00, extended-life tube, tunability, UV and service contracts. American Laser Corp., 1832 S. 3850, W., Salt Lake City, Utah 84104. A hard-sealed, integral-mirror, plane-polarized helium-cadmium laser, the Model 43001, exhibits a typical polarization ratio higher than 1000:1. Measuring 4.times.4.times.24 inches with a full Invar resonator, this laser offers high power stability ([plus-or-minus]) 1 percent over one hour), low noise ([is less than or =]) 1 percent rms) and an extended warranty period (4000 hours or one year to half power). The laser is also available with random polarization or with frit-sealed, fused-silica Brewster windows for those users switching between 325 and 442 nm operation. Liconix, 1390 Borregas Ave., Sunnyvale, Calif. 94089.

Brief Summary Text (39):
A digital video CCD Camera and scientific investigations is available. This camera features high-resolution, true random triggering, high-light gain with optional image intensifiers, digital and standard video outputs, digital frame store and on-board video monitor, digital delay and exposure-time controls, and sequence operation for stroboscopic photography. Applications include ballistics, detonics and other high-speed photography including laser and fusion research and spectroscopy. Marco Scientific, Inc., 1055 Synnyvale-Saratoga Rd., #8, Sunnyvale, Calif. 94087.

Brief Summary Text (42):
Herschelian-mounted remote sensing receivers and radio-metric systems are available from Lambda/Ten Optics. They have Herschelian-mounted Newtonian telescopes and

collimators. These all-reflective instruments have no central obscuration and locate the focal plane to the side of the collimator/telescope. Used as a collimator, the Lambda/Ten "NC Series" projects a collimated beam from the light source to infinity. As a telescope the unit images light from a distance to the focal plane. The series is ruggedized in a heat-treated aluminum tube, fully self-supporting, and mountable in any orientation. Lambda/Ten Optics, 1 Lyberty Way, Westford, Mass. 01886.

Brief Summary Text (47):
As a system, the invention is useful for locating and defining the position of an object in relation to a known area or tract. A plurality of point-sources of electromagnetic radiation, e.g. superbright LED's are located, respectively, at each of at least three reference points in defined relationship to each other and to said area or tract. An angle measuring sensor for said electromagnetic energy, e.g. a CCD sensor system, is positioned at an unknown location P.sub.0 and in known relation to the object the location of which is to be defined. The sensor is constructed and configured to measure angles defined by lines extending through P.sub.0 and at least two of a first set of said reference points and angles defined by lines extending through P.sub.0 and at least two of at least one additional set of reference points, respectively, the respective sets of reference points being different from each other and being selected such that a geometric figure defined by P.sub.0 and the first set overlaps a geometric figure defined by P.sub.0 and at least one additional set of reference points. A computer is connected to said sensor for receiving data defining said measured angles and input data defining the relationship of said reference points to each other and to said tract or area and for computing data defining the location of P.sub.0 in relation to said tract or area and means are provided to cause the computed definitional data signal derived from said computed data defining the location of P.sub.0 to a display or control means. The definitional data signal my be used for controlling the movement or operation of the object. The system may function in a single plane or in three dimensions and may use three-dimensional data to define location in a single plane, or in three dimensional space.

Detailed Description Text (10):
In the special case where the points lie on a straight line on or adjacent the tract or area of interest, the location of P.sub.0 can be calculated as in the general case or as described here, making reference now to FIGS. 1, 2 and 8. The coordinates of points P.sub.1, P.sub.2 and P.sub.3 are known. These three points preferably but not necessarily would be at one edge or slightly outside the project to be worked upon and lie on the same line with each other. This arrangement is for simplification and to eliminate one of two solutions that is mathematically possible.

Detailed Description Text (20):
(a) Point electromagnetic radiation sources, e.g., point-light source transmitters, are placed at three or more reference points that are in known, defined relationship to each other and to the tract or area of interest.

Detailed Description Text (25):
(g) The mathematical calculations described to define the location P.sub.0 relative to one or more reference indicia relative to the area or tract are executed, typically by a computer that receives data directly from the sensors, thereby define the location P.sub.0 on or in relation to the tract or area of interest.

Detailed Description Text (29):
The point-source light may send out a pulse coded sequence of light bursts which serves to identify the particular point to send short, intense pulses for longer range without large average power requirements or special equipment. The light transmission is preferably omnidirectional in the X and Y direction and covers approximately 30.degree. above and below the X-Y plane in the Z direction. In a

preferred embodiment, the light transmitter consists of a radial cluster of superb fight infrared light emitting diodes or diode lasers with lenses. The typical emission maximum is around 880 Nm. The transmitter, once activated, can continuously transmit the pulse coded information sequence. A Dalsa, Inc., CCD camera having a CCD sensor having 256.times.256 pixels and a 50 mm lens using an infrared filter to block light below 800 nm may be used in connection with an infrared superbright light emitting diode, Siemens pan No. SFH484 as the point source. Greater accuracy can be accomplished using, for example, a 4000 pixel array such as is market by Dalsa. These are, of course, merely exemplary.

Detailed Description Text (37):
In a preferred embodiment, the image of the point source transmitter is focused on the sensitive elements of a photo detector array. The electronics scan the array and determine the position of the image on the detector surface. Since the image position on the detector corresponds to the location of a particular point, e.g. P.sub.1, the precise angle between such point, e.g. P.sub.1, and another point P.sub.2 can be determined. The radiation sensing devices can be mounted in the sensing system with great exactitude relative to each other. The radiation sensing devices can also be mounted and position to have precisely known relationships between the fields of view of the respective sensors, or of a single sensor in different positions. A single sensor system with wide-angle sensors would be capable of viewing, in fields that meet or overlap, in a 360.degree. solid angle, with, perhaps, some minor interference from the hardware of the sensor system per se. This capability eliminates the need for mechanical or electro-mechanical angle measuring or calibrating devices. Using point sources at known locations, calibration can be checked or adjusted, if ever necessary using only the sensor and computer systems. This is very simple where the two point sources are detectable by a single sensor in the sensor system.

Detailed Description Text (38):
Although various types of photo detectors can be used including photodiode arrays, vidicon tubes and others, the preferred method involves the use of charge coupled devices (CCD). CCDs have precision pixels (picture element) arranged in various formats. The image scanning is simple to do with computer driven image analyzers. In addition, systems with high IR sensitivity are available. To increase specific signal to background signal, it may be desirable to place an IR pass filter in front of the detector; all other light will then be blocked. CCD image sensors such as manufactured by Dalsa, Inc., Waterloo, Ontario, Canada, are suitable.

L11: Entry 3 of 13 File: PGPB Feb 19, 2004

DOCUMENT-IDENTIFIER: US 20040032493 A1
TITLE: Method for monitoring the interior and/or exterior of a vehicle, and a vehicle having at least one survaillance camera

Abstract Paragraph:
A method for monitoring a space of a vehicle. The method includes sensing the space using a first sensor including at least one surveillance camera so as to produce an image data, performing an evaluation of the image data, selecting at least one area of the space using the evaluation of the image data, sensing the at least one area using a second alignable sensor having a restricted spatial sensing range so as to produce a second data, and evaluating the second data. In addition, a vehicle that includes a first sensor having at least one surveillance camera disposed in an interior of the vehicle, the first sensor having a field of view at least partially covering at least one of the interior and an exterior of the vehicle, and a second alignable sensor having a restricted spatial sensing range, an alignment of the second sensor being controllable using the first sensor.

Summary of Invention Paragraph:
[0002] The invention relates to a method for monitoring the interior and/or exterior of a vehicle, and to a vehicle having at least one surveillance camera in the vehicle interior.

Summary of Invention Paragraph:
[0003] Motor vehicles having a camera in the vehicle interior are known, for example, individual cameras with a field of view to the outside can be used to monitor the front, side and/or rear spaces through the window panes of the vehicle. Again, cameras have already been proposed for observing parts of the vehicle interior, for example in German Patent Application No. DE-A-198 03 158, which exhibits a device for optically determining the state of vigilance of the operator of a vehicle.

Summary of Invention Paragraph:
[0004] The unpublished German patent application previously applied for by the applicant and having the official file reference DE 101 58 415.6 discloses a method for optically monitoring the interior of a vehicle with at least one surveillance camera. In this case, the sensing of the exterior is also represented by at least one surveillance camera. This described mode of procedure requires complicated evaluation of the image data, the informativeness of the evaluated data not always being sufficient.

Summary of Invention Paragraph:
[0006] The present invention provides a method for monitoring the interior and/or exterior of a vehicle having a sensor that is formed by at least one surveillance camera, in the case of which the interior and/or exterior is sensed by the surveillance camera and the image data are evaluated, wherein the evaluation is used to select at least one area, and wherein this area is sensed by means of a second alignable sensor with a restricted spatial sensing range and the data recorded by the second sensor are subjected to an evaluation. The present invention also provides a vehicle having a first sensor which is formed by at least one surveillance camera in the interior of the vehicle and whose field of view at least

partially covers the interior and/or exterior of the vehicle, wherein a second sensor is provided which has a restricted spatial sensing range and whose alignment can be controlled as a function of the first sensor.

Summary of Invention Paragraph:
[0008] In accordance with the present invention, the vehicle interior and the vehicle exterior, as well, are observed by means of at least one surveillance camera that comprises, in a preferred embodiment, a conventional digital, particular CCD, camera and a, for example, spherically or parabolically convex mirror that is set apart from the camera and is observed, in turn, by the camera. Surveillance cameras in an integrated housing have also proved themselves, in addition. Surveillance cameras are described, for example, in PCT international patent publications WO 99/30197, WO 99/45422 and WO 97/43854, and are used, for example, for monitoring purposes and in the case of robot navigation. They typically produce a 360.degree. panoramic image in a way similar to a fish eye camera. Unlike fish eye cameras, which virtually no longer permit details to be recognized on the taking horizon, that is to say at the edge of its azimuthal taking range of max. 180.degree., surveillance cameras also reproduce details in the edge region of an image and thereby even permit, if appropriate, azimuthal taking ranges of more than 180.degree..

Summary of Invention Paragraph:
[0009] Given a suitable arrangement of the surveillance camera, in particular in the region of the inside mirror, a very large part of the vehicle interior, and also of the vehicle exterior, can be sensed at once. It has also proved effective to arrange a convex mirror in the vehicle interior on the vehicle roof, as a result of which the entire hemisphere situated therebelow, that is to say virtually the entire vehicle interior, and also the exterior that can be sensed through the side window panes, can be taken.

Summary of Invention Paragraph:
[0010] It has proved effective, furthermore, to integrate the convex mirror or the camera itself in the dashboard, in particular when it is principally the front area of the vehicle interior and the area in front of the vehicle that are to be monitored. Image data recorded by the surveillance camera can be used to select an interesting area for a more detailed evaluation, and to make use, for a more detailed evaluation, of a second sensor, which is distinguished by a spatially restricted sensing range and is designed to be capable of alignment such that it can be aligned with an area classified as interesting. The data recorded by the second sensor are subjected to an evaluation that gives more detailed information relating to the selected area than is generally permitted by the surveillance camera alone.

Summary of Invention Paragraph:
[0011] The present invention creates a method that can make available reliable information in relevant, selected areas of the exterior or else the interior of the vehicle. The comprehensive recording of the image data of the surveillance camera renders possible a very reliable sensing and selecting of the relevant area or areas of particular interest, without it being possible to overlook or not consider individual areas that can be important for a driving decision. In order to permit a reliable driving decision, the method according to the present invention or the vehicle according to the present invention is used by selecting particularly relevant areas and feeding them to more detailed sensing by a second sensor, in particular one with special properties. The reliability of evaluation, and thus also the driving safety, are substantially increased thereby.

Summary of Invention Paragraph:
[0012] On the basis of the recorded and evaluated image data, the driver can be warned at an early stage, on the one hand, and on the other hand it is possible to effect measures to prevent accidents by means of active intervention in the

vehicle, or else to effect measures to limit the severity of consequences of accidents, for example by early triggering of airbags or the like.

Summary of Invention Paragraph:
[0013] According to a particularly preferred embodiment of the present invention, the second sensor is formed from at least a digital camera, an infrared camera, a laser point sensor, a radar sensor or a combination thereof. As a result, the laser point sensor or the radar sensor, in particular, create a very reliable evaluation of the relative behavior of the sensed, selected area of the second sensor in relation to the vehicle. In particular, the relative speed or else the distance from the vehicle is sensed, evaluated and made available for further processing in the vehicle. Precisely through use as second sensors of sensor types that reliably permit sensing of the relative speed of objects in the sensed area, very important information is obtained for preventing, or limiting the consequences of, accidents, and this benefits the driving safety of the vehicle itself, but also of the traffic as a whole, in particular the safety of pedestrians. However, infrared cameras or digital cameras with a relatively large magnification factor, in particular with a zoom function, also prove to be very useful, since they additionally permit substantially more detailed information to be obtained, in particular under unfavorable situations such as fog or dusk or night, in relation to the information obtained by the surveillance camera. This additional information is made available to the vehicle per se or in combination with the data from the first sensor, and the vehicle is correspondingly controlled to enhance traffic safety.

Summary of Invention Paragraph:
[0014] The alignment of the second sensor is preferably performed on the basis of an automated evaluation of the image data of the first sensor, by virtue of the fact that the second sensor is swiveled either by motor, and thereby swivels the restricted sensing range onto another area of the sensing range of the surveillance camera, or electronically, as performed, for example, in the case of a changed drive or phased array radar antenna. In the case of the latter, one and the same radar antenna achieves a different directional characteristic by differentiated driving, without the need for the antenna to be swiveled mechanically or by motor relative to the sensor. Such an electronic alignment of the second sensor proves to be very advantageous, since mechanically swivelable sensors have proved to be very susceptible owing to the continuous shaking and vibration in vehicles.

Summary of Invention Paragraph:
[0015] The alignment of the second sensor is preferably carried out on the basis of automated evaluation of the image data, methods for the analysis of movement, contour and/or color having proved themselves, in particular, for evaluating image data. This evaluation of the image data of the first sensor results in automated selection of an area of particular interest which is subsequently subjected to a thorough more detailed observation by the second sensor. In this case, it has proved to be particularly effective to carry out the selection of the area of interest with the aid of an evaluation of movements in the image of the first sensor, for example by using the optical flux, and this has proved to be particularly effective in the case of using the present invention in conjunction with a device for restricting or preventing collisions with pedestrians or cyclists.

Summary of Invention Paragraph:
[0016] Since the images obtained by the at least one surveillance camera are greatly distorted, that is to say are present in some form of curvilinear "world coordinates", one or more undistorted partial images are generated therefrom by transforming the images of the camera into cylindrical or plane coordinates. The relationship between the curvilinear coordinate system of the camera images and the cylindrical or plane target coordinate systems is fixed by the mirror geometry and camera and/or by the structure of the surveillance camera. In the transformation, the values of brightness and, if appropriate, color of each image point of a camera

image are assigned to a point in the cylindrical or plane coordinate system, whose coordinates result from trigonometric relationships, for example in the case of a spherical mirror.

Summary of Invention Paragraph:
[0017] The corresponding calculations can be carried out substantially in real time in a computer in the vehicle; in order to save computing power, the described assignment is carried out in practice, however, preferably with the aid of one or more transformation tables that are drawn up during a camera calibration and stored for the purpose of use during the camera operation in an onboard computer or a hard-wired electronic image rectification system.

Summary of Invention Paragraph:
[0018] This leads to one or more partial images of the vehicle interior in the case of which substantially only a one-dimensional distortion is present (in the case of a transformation to cylindrical coordinates) or (in the case of a transformation to plane coordinates) no distortion at all is present any more, and so straight lines are essentially reproduced as straight lines. Such images in cylindrical or plane coordinates can then be further processed electronically in a very simple way, in particular they can be evaluated very simply. This permits simple further processing, and thus cost-effective implementation of the present invention in a vehicle. In particular, the evaluation, the selection of a particularly interesting area for closer evaluation by the second sensor with the aid of a selection stage, is made substantially easier. Moreover, it is possible by this transformation to achieve a modularization of the monitoring system for a vehicle, and this permits a simple replacement of the at least one surveillance camera with subsequent transformation to the respective circumstances of a vehicle in conjunction with largely identical subsequent image processing and evaluation with selection of the areas of interest. It is thereby possible to lower substantially the costs for such systems for monitoring the interior and exterior of a vehicle, and thereby to raise the acceptance to the user without appreciable loss in the reliability of evaluation.

Summary of Invention Paragraph:
[0019] The present invention also relates to a vehicle having a first sensor that is formed by at least one surveillance camera in the interior of the vehicle, whose field of view at least partially covers the interior and/or exterior of the vehicle. The first sensor is assigned a second sensor that has a restricted spatial sensing range of which the alignment can be controlled as a function of the first sensor. In this case, the alignment is preferably performed via a control unit that can be controlled on the basis of automated evaluation of the image data of the first sensor, which is preferably carried out by an image evaluation unit, such that a selected region, classified as particularly interesting or relevant, of the visual range of the first sensor is specifically sensed by the second sensor and thoroughly evaluated. In this case, the alignment of the second sensor is performed by means of a control unit that swivels the second sensor preferably by motor, or adapts its alignment correspondingly in an electronic way. The result of this is a preferably automated recording of the relevant information from the exterior or interior of the vehicle with the aid of the selection by a selection stage in conjunction with a corresponding control unit, which is assigned to the first sensor, and a very reliable mode of operation is thereby provided for the method for monitoring the interior and exterior of a vehicle.

Summary of Invention Paragraph:
[0020] It has proved to be especially advantageous either to use the first and/or the second sensor per se in each case, or to use them in common as a stereoscopic sensing system for the interior and/or exterior of the vehicle. Consequently, the recorded information of each sensor which is formed at least by two individual sensors is, for example, formed by two surveillance cameras or from two digital cameras, two infrared cameras, two laser point sensors or two radar sensors or a

combination of two such individual sensors in such a way that a stereoscopic evaluation of the sensing range is possible with two individual sensors. In the course of this stereoscopic evaluation, it is possible, in particular, to record and evaluate information relating to the depth graduation of the objects in the sensing range and, in particular, information relating to the distance or else to the change in distance, that is to say the relative speed. This stereoscopic information permits warning functions to be activated very specifically, or activation of defensive strategies for preventing or limiting the effects of accidents by early activation of defensive measures, so-called precrash measures, or else with regard to intervention in the driving behavior of the vehicle, for example by means of independent, autonomous braking or evasion of the vehicle. It is thereby particularly the information relating to the spatial breakdown of the exterior of a vehicle, particularly in the front region, that forms the basis of the control.

Summary of Invention Paragraph:
[0021] The use of infrared cameras, laser point sensors and/or radar sensors results in a very reliable way in expansion of the information content of the sensible surroundings in the interior and/or exterior of the vehicle via the information content of a camera that substantially operates exclusively in the visible frequency range. A substantially differentiated representation of the information relating to the surrounding area is thereby rendered possible and made available for later evaluation of the vehicle.

Summary of Invention Paragraph:
[0023] It has proved to be particularly effective to arrange the first sensor, which includes one or two or also more surveillance cameras, in the roof area, particularly in the region of the inside mirror, and this results in a very advantageously structured sensing range of the first sensor. In particular, the lateral area and the front area of the vehicle can be very effectively sensed through the window panes of a vehicle here, but also so can the interior, in particular the area of the front seats, and can therefore be evaluated very easily with regard to the selected areas.

Summary of Invention Paragraph:
[0026] By contrast with the case of other conventional optical sensor systems for vehicles, the combination of the at least one surveillance camera in conjunction with the second alignable sensor with a restricted field of view permits a reduction in the number of the cameras required for carrying out the multiplicity of possible tasks in recording information from the interior and/or from the exterior.

Summary of Invention Paragraph:
[0027] In addition to said possible application of the present invention in conjunction with assistant systems for the detection of traffic lights, detection of traffic signs, methods for tracking traffic jams, lane detection, detection of the right/left situations, object detection in the near field, such as cyclists, for example, or sensing and evaluating the situation at an intersection, it is also possible to implement other applications such as an interior monitoring for antitheft security or for documenting traffic situations, particularly in connection with accidents. The applications and image evaluation systems that come to be applied in connection with the present invention do not require calibrated systems; it is also possible to use uncalibrated systems. Again, it is possible to apply the present invention in other vehicles, which are not automobiles, particularly in aircraft or ships, for example for monitoring tasks.

Brief Description of Drawings Paragraph:
[0030] FIG. 2 shows a sketch of an image of a surveillance camera; and

Brief Description of Drawings Paragraph:

[0031] FIG. 3 shows a rectified partial image in accordance with FIG. 2.

Detail Description Paragraph:
[0032] An exemplary design of an arrangement according to the present invention for monitoring the interior and/or exterior of a vehicle having two surveillance cameras is illustrated in FIG. 1.

Detail Description Paragraph:
[0033] The first surveillance camera comprises a spherically or parabolically convex mirror 1 and a digital camera 2 that constitutes a CCD camera. A second surveillance camera is constructed correspondingly from a second mirror 3, which is designed as a spherically or parabolically convex mirror 3, and from a CCD camera 4. The two mirrors 1, 3 are arranged on the roof of the vehicle in the interior. The two cameras 2, 4 are arranged below the two mirrors 1, 3 and have the two mirrors 1, 3 in their field of view, in particular comprising the essential field of view of the cameras 2, 4. Such surveillance cameras are described in, for example, said international patent documents WO 99/30197, WO 99/45422 and WO 97/43854. The convex mirror 1 is fitted in this example on the roof above the area between the front seats, the reflecting surface pointing downward, and the assigned camera 2 being fastened between the two front seats with sight line upward in the direction of the mirror 1. The second convex mirror 3 is arranged in the middle of the vehicle roof. Its reflecting surface likewise points downward. The camera 4 is arranged below the mirror 3 in the footwell of the vehicle in the rear compartment in the region of the transmission tunnel such that it is aligned with the mirror 3.

Detail Description Paragraph:
[0034] In the case of this arrangement, the camera 2 or 4 sees in the assigned convex mirror 1, 3 an image of the hemisphere below the roof of the vehicle as illustrated schematically by way of example in FIG. 2. Here, with the exception of a mechanically or electronically masked central region in which it would image itself, the image shows the hemisphere named above. As may be gathered from FIG. 2, the camera senses not only the interior with the seats and the vehicle occupants, it is also capable of sensing the area outside through the windscreen, details of the exterior not having been illustrated in FIG. 2, in order to improve comprehensibility. The illustration was limited to reproducing the window panes, in order to improve clarity, and so the exterior is not reproduced.

Detail Description Paragraph:
[0035] The digital image data supplied by the cameras 2, 4 are strongly distorted, since they image the surroundings in spherical or some other curvilinear coordinates, depending on the shape of the mirror. Each image of the cameras 2, 4 is fed to a rectifying unit 5 in which one or more parts of the image are transformed to plane coordinates. An exemplary transformed image of the driver side is illustrated in FIG. 3. The image illustrated shows a relatively undistorted image in which straight lines are also reproduced as substantially straight lines.

Detail Description Paragraph:
[0036] The transformed image data are fed to a selection stage 6 which is now enabled in a simple way on the basis of the transformed, rectified image data to select interesting areas of the image recorded by the cameras 2, 4 by analyzing contours, colors and movements, for example using the concept of optical flux.

Detail Description Paragraph:
[0037] If the arrangement is used to monitor the interior and/or exterior in the case of a pedestrian monitoring unit, it is preferred to use a selection stage with movement analysis, while given an application as a traffic lights or traffic signs assistant it is analysis by means of a contour and/or color that are/is applied. If, in an automated process, the selection stage determines an area as particularly relevant, and thereby selects this area, an item of information representing this

selected area is reported by the selection stage 6 to the control unit 7 which then uses the alignment unit 8 to swivel the second sensor 9, which includes a CCD camera with zoom function, to the effect that the field of view of the second sensor 9 covers this selected area. Here, the magnification factor (zoom factor) of the second sensor 9 is set by the control unit 7 such that the objects in the selected area can be sensed in detail. The zoom factor is selected here in accordance with the distance, determined by a stereoscopic measurement, of the selected area or of the objects in the selected area.

Detail Description Paragraph:
[0038] The stereoscopic measurement is performed in this case via the two surveillance cameras 1, 2/3, 4, which together form a stereoscopic surveillance camera. The stereoscopic evaluation is performed here by the selection stage 6, which makes available the distance information of the control unit 7, which consequently controls the zoom of the second sensor 9.

Detail Description Paragraph:
[0039] The image data recorded by the second sensor 9 and the two surveillance cameras 1, 2/3, 4 are fed to an image evaluation unit 10 that permits an overall evaluation of the image data of all the sensing systems, and thus of the two sensors, that is to say the first surveillance camera 1, 2, the second surveillance camera 3, 4 and the zoom camera 9. It is possible in the course of the overall evaluation in particular to resolve instances of ambiguity and/or to permit a very specific evaluation of the spatial subdivision of the sensed exterior and/or interior. As a result, it is possible in particular to determine distances and/or positions of objects individually sensed. Moreover, relative speeds of sensed objects can also be calculated in relation to the vehicle or to the sensor arrangement. It is possible precisely by means of the exemplary overall evaluation of all image information to obtain information that is very informative and reliable for the purpose of constructing the exterior and/or the interior of the vehicle. With the aid of this secure and reliable information, other components of a vehicle can make necessary measures available, for example warnings to the driver or codriver or measures for further information for the driver and/or co-driver, and/or initiate measures for reducing effects of accidents such as, for example, early inflation of airbags or early inclining of the engine hood before a pedestrian impact on the vehicle, or measures for automatically braking or accelerating a vehicle or avoiding contact by it. For this purpose, the required information of the image evaluation unit is made available to these other components of the vehicle via an interface 11.

Detail Description Paragraph:
[0040] The method according to the present invention is suitable in a particularly advantageous way for use in vehicles, particularly in conjunction with a device for protection against theft, or with a device for transmitting image data. In particular, the image data are transmitted via a mobile radio telephone to persons, for example an owner of a motor vehicle, as soon as the alarm system or the antitheft device is activated.

Detail Description Paragraph:
[0041] Moreover, the present invention is particularly suitable for cooperating with a recording system that senses and stores the driving situation at the same time as an accident both in the interior and in the exterior of the vehicle such that a later analysis of the accident is permitted. Owing to the cooperation of the two sensors once as panoramic sensor (surveillance cameras), and once as selected sensor (second sensor) for particularly relevant areas, it proves to be very helpful that precisely the information that is particularly important for an accident situation, for example the overall view, but also special areas can be sensed and documented specifically.

CLAIMS:

1. A method for monitoring a space of a vehicle comprising: sensing the space using a first sensor including at least one surveillance camera so as to produce an image data; performing an evaluation of the image data; selecting at least one area of the space using the evaluation of the image data; sensing the at least one area using a second alignable sensor having a restricted spatial sensing range so as to produce a second data; and evaluating the second data.

4. The method as recited in claim 3 wherein the aligning of the second sensor is performed using a control unit based on the evaluation of the image data.

7. The method as recited in claim 4 wherein the evaluation of the image data is performed automatically using the control unit.

8. The method as recited in claim 7 wherein the evaluation of the image data includes analyzing at least one of a movement, a contour and a color.

10. The method as recited in claim 1 wherein the image data has curvilinear coordinates and further comprising transforming the image data so as to have cylindrical or plane coordinates before the evaluation of the image data is performed.

11. A vehicle comprising: a first sensor including at least one surveillance camera disposed in an interior of the vehicle, the first sensor having a field of view covering at least one of a portion of the interior and a portion of an exterior of the vehicle; and a second alignable sensor having a restricted spatial sensing range, an alignment of the second sensor being controllable using the first sensor.

12. The vehicle as recited in claim 111 wherein the first sensor produces image data and further comprising: an electric or motor drive; a control unit; and a selection stage for performing an automated evaluation of the image data, wherein the drive and the control unit are configured to align the second sensor using the automated evaluation.

14. The vehicle as recited in claim 11 wherein the first sensor includes two surveillance cameras jointly forming a stereo image camera.

15. The vehicle as recited in claim 11 wherein the second sensor includes at least one of a digital camera, an infrared camera, a laser point sensor and a radar sensor.

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